(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
4 January 2001 (04.01.2001)

PCT

(10) International Publication Number
WO 01/01082 A1

(51) International Patent Classification[7]: G01F 1/68, A01K 1/00

(21) International Application Number: PCT/IB00/00865

(22) International Filing Date: 28 June 2000 (28.06.2000)

(25) Filing Language: Dutch

(26) Publication Language: English

(30) Priority Data:
1012459 28 June 1999 (28.06.1999) NL

(71) Applicant (*for all designated States except US*): KATHOLIEKE UNIVERSITEIT LEUVEN [BE/BE]; Groot Begijnhof 59, B-3000 Leuven (BE).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): BERCKMANS, Daniel, Albert [BE/BE]; Slangenstraat 37, B-3010 Kessel-Lo (BE). VRANKEN, Erik, Joannes, Matheus [BE/BE]; Molendijkstraat 151, B-3582 Beringen (BE). JANSSENS, Karl, Hans, Bert [BE/BE]; Tervuursesteenweg 178, B-3001 Heverlee (BE).

(74) Agent: PRINS, A., W.; Vereenigde, Nieuwe Parklaan 97, NL-2587 BN The Hague (NL).

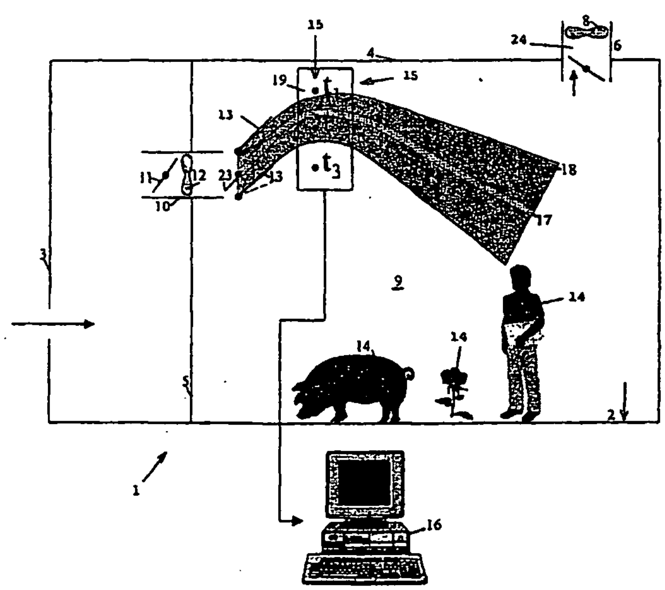
(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR DETERMINING A FLOW PATTERN OF A FLUID IN A SPACE



(57) Abstract: A method for determining a flow pattern of a gas in a space, wherein: gas is passed via at least one inlet into the space, in a first position, at a distance from the at least one inlet a temperature distribution, at any rate at least two temperatures in at least a part of the gas stream is measured, on the basis of the measured temperature distribution, at least of the measured temperatures the position of the maximum or minimum temperature is determined, and on the basis of at least the position of this maximum or minimum temperature the flow pattern in the space is determined, preferably by means of an algorithm.

WO 01/01082 A1

— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

Title: Method and apparatus for determining a flow pattern of a fluid in a space.

The invention relates to a method for determining a flow pattern of a fluid in a space.

In all kinds of applications it is important to be able to determine a flow pattern of a fluid. Thus, for instance, in climate controls in, for instance, stables and such agrarian constructions, greenhouses, warehouses, working and living spaces and in other spaces, use is made of data concerning the throughput of a gas stream introduced into the space, the temperature of the introduced air and the temperature in the space. These data are used to regulate, for instance, the inlet opening for the gas stream to be introduced. Efforts are thus made to obtain such a distribution of the gas stream in the space that an optimum climate is obtained for, for instance, living organisms present therein. Demonstrable is that the conditions of life of animals and men in a space are considerably improved by a proper climate control in the space, which is ergonomically and, moreover, economically advantageous, because as a result thereof the yield per animal can be increased, while, moreover, the health of man, animal and plant is positively influenced.

It has been found that by means of the regulations now available no optimum climate control is possible. An important reason therefor is that it has hitherto not been found possible to unambiguously and readily determine flow patterns of gases in the space, preferably during use of the space. In particular, it has been found that dynamic, preferably continuous measurement of the flow pattern of gas streams in the space has hitherto not been possible, at least requires very complex and very expensive arrangements. These known arrangements are therefore not suitable for continuously measuring air patterns during the control thereof.

It is further important, for instance in aeration tanks for waste water, that a proper distribution of a gas stream through the waste water is obtained. This has hitherto been adjusted mainly on the basis of visual observation and

experience. It will be clear that, in general, no ideal adjustment will thus be obtained. Moreover, this can only be examined by measuring afterwards and not in situ.

Furthermore, when mixing via liquids, for instance in the preparation of paints and lacquers, foodstuffs, medicaments and the like, it is highly important that a complete mixing is obtained. Here, too, it has hitherto not been possible to measure in situ the flow pattern of a liquid stream passed into a tank or the like.

It is an object of the invention to provide a method of the type described in the opening paragraph, in which the above drawbacks are avoided. In particular, it is an object of the invention to provide a method with which the flow pattern of fluid streams in a space can be determined dynamically, in situ, in a relatively simple and unambiguous manner and at relatively low cost. To this end, a method according to the invention is characterized by the measures of claim 1.

Determination of a flow pattern of fluid flows in a space offers the advantage that it can be accurately determined how, for instance, temperature and flow velocity distributions in the space occur. With a method according to the present invention the flow pattern of a fluid stream can be determined in a relatively simple manner and with economic means, for instance from an inlet in a space, in particular by determining a so-called central line thereof and making use of the fact that, in principle, the distribution of magnitudes in an air stream is distributed normally, at least in the known manner, around this central line, at least can be properly estimated. The central line is determined by the connecting line between a relevant inlet and the positions of the maximum or minimum value measured, at least calculated, of the magnitude in the gas stream at the level of the or each sensor. Whether this is determined by the minimum or maximum value, of course depends on the value of the magnitude of the inflowing fluid with respect to the relevant magnitude in the further space. When, for instance, inflowing fluid is relatively cold, use will be

made of the minimum temperature at the level of the of each first sensor. When the fluid stream has a relatively high temperature, use will be made of the maximum temperature, starting from temperature as measured magnitude.

It will be clear that on the basis of the flow pattern thus determined it can be determined whether this corresponds to a desired flow pattern, after which, if necessary, readjustment can be effected, for instance by changing the inflow direction, the inflow throughput, heating or cooling, at least treatment of the inflowing fluid stream or of the space, use of by-pass means and the like. Exactly because the flow pattern of the or each fluid stream in the space can be determined accurately and unambiguously, at any desired moment, optimum measurement and/or regulation in the space becomes possible, for instance of the climate or of measurement thereof. The use of an algorithm, for instance included in a process unit, such as a computer, offers the additional advantage that a simple comparison of the determined flow pattern with, for instance, previously inputted desired flow patterns is possible, with the result that regulation becomes even more easily possible. Moreover, an algorithm is very suitable for determining, on the basis of the measured value, the position of the central line and thus of the flow pattern of the or each fluid stream. Because of this, practically instantaneous adjustment is possible. An apparatus for use in a method according to the invention can be carried out in a self-learning manner.

In a first very advantageous embodiment a method according to the invention is characterized by the measures according to claim 5.

By placing in the or each above first position a sensor with which in at least two and preferably at least three spaced apart positions the value of the relevant magnitude in the fluid can be measured, the advantage is obtained that on the basis of, for instance, a weighed average the position of the maximum or minimum value in the above first position in the fluid stream can be relatively readily determined. Thus the position of the central line in

the above first position is unambiguously fixed. When use is made of at least three recording elements placed at a known mutual distance from each other, the additional advantage is obtained that the intersection point of the central line with the above first position can be determined, practically independently of further data, such as the value of the relevant magnitude in the surroundings, while, moreover, an excellent estimation of the height of the relevant maximum or minimum value can be made. It will be clear that the use of a larger number of recording elements may enable an even better estimation of the position of the central line and the height of the value prevailing there, in particular when the normal distribution of the relevant value in the fluid stream deviates, but that as a result thereof the cost of such a method will increase, for instance as a result of the required hardware. Depending on the conditions of use and the wishes of the user, in particular the desired accuracy, those skilled in the art can readily determine the optimum number of sensors, the optimum configuration of the recording elements and the positioning thereof with respect to each other.

In a further elaboration a method according to the present invention is further characterized by the measures of claim 8.

Regulation of the inflow throughput of the fluid stream in the space on the basis of the determined flow pattern, if required related to a desired flow pattern, offers the advantage that the flow pattern can be relatively easily readjusted, so as to further optimize it, for instance in the direction of the desired flow pattern.

Regulation of the inflow direction of the fluid in the space offers a further or alternative possibility to adapt the flow pattern of the or each fluid stream in the space on the basis of the or each determined flow pattern, in particular on the basis of a recorded difference between a desired flow pattern and an actual flow pattern.

The foregoing already shows that by means of a method according to the present invention a substantially closed regulating system can be obtained

with which, if desired, the flow pattern of the or each fluid stream in the space can be determined and readjusted practically continuously.

Inputting data about the relevant values in the fluid stream, the throughput and/or the composition thereof when it flows out of the space in an algorithm for the control of, for instance, climate or mixing in the space offers the advantage that an even more accurate regulation is possible, in particular of the flow pattern of the or each fluid stream, while, moreover, for instance the discharge of too much heat from the space can be prevented, without the occurrence of undesirable fluid compositions in the space. Also, these data, for instance a difference between inflow throughput and outflow throughput, can be used for the determination and regulation of any pressure build-up in the space.

In a further alternative embodiment a method according to the invention is characterized by the measures according to claim 9.

The use of a method according to the invention, in which as fluid a gas is passed into a space, and in which at least one of the above magnitudes is measured, the advantage is obtained that, for instance for the purpose of climate control or aeration in spaces such as stables, working or living spaces and the like, flow patterns can be determined. The measurement of the temperature is very suitable in this respect, in particular because of the relatively simple recording elements available therefor, but also other energy and mass variables such as flow velocity or flow direction, pressure or density of the gas stream, gas concentration and the like can be measured as magnitude. When for the relevant space the distribution or presence of a specific component, such as, for instance, oxygen, nitrogen, carbon mono- or dioxide or the like is important, recording elements arranged therefor can be used.

A method according to the invention can be used both for flow of gases in gases and for flow of gases in liquids.

In a further alternative embodiment a method according to the invention is characterized by the measures according to claim 12.

To determine flow patterns of a liquid stream passed into a space, in particular into a space filled with liquid, such a method is very suitable, because on the basis of the measured magnitudes such as temperature, flow velocity or flow direction, pressure, concentration or density the relevant flow pattern can be determined rapidly, easily and accurately and can be readjusted on the basis thereof, so that, for instance, a proper mixing can be obtained or, on the contrary, can be inhibited..

The invention further relates to an apparatus for determining a flow pattern of a gas in a space, characterized by the features according to claim 14.

With such an apparatus the flow pattern of a fluid stream in a space can be determined in a very easy, accurate and economic manner. Such an apparatus is very suitable for use of a method according to present invention.

In a further elaboration an apparatus according to present invention is characterized by the features according to claim 19.

By providing at least one and preferably a series of first sensors, each first sensor comprising at least two, and preferably at least three recording elements which are placed at a known mutual distance from each other, the advantage is obtained that per first sensor, on the basis of, for instance, a weighed average or by using an estimated curve in the local fluid stream, the position of a minimum or maximum value of the measured magnitude at the level of the relevant first sensor can be readily determined, as well as, if desired, the height thereof, while a series of first sensors placed one after another very readily enables the determination of a curve by the points with the above minimum or maximum values at the first sensors. This curve represents the central line of the flow pattern of the relevant fluid stream. A larger number of first sensors will of course enable a more accurate determination of this central line.

In a further advantageous embodiment an apparatus according to the invention is characterized by the features according to claim 21.

The incorporation of the first measuring device, the process unit and fluid inlet regulating means and/or fluid outlet regulating means into a regulating cycle offers the advantage that regulation of the fluid stream, in particular of the flow pattern thereof and inflow and outflow throughput and/or direction can be determined and readjusted. By making use of suitable algorithms, both regulation afterwards and advance regulation are possible with such an apparatus. The fluid inlet regulating means and/or fluid outlet regulating means may be adjusted, for instance, on the basis of an existing flow pattern, an eventually desired flow pattern and, if any, different external factors, such as, for instance, changes in the filling of the space. It can thus be ensured, for instance, that in a stable the desired flow pattern is practically immediately obtained when additional animals are placed therein or are removed therefrom, when additional heating is effected in the space or, for instance, inlet openings or outlet openings are additionally provided or are closed.

The invention further relates to a space provided with an apparatus according to the invention, to a process unit for use in a method, an apparatus or a space according to the invention, and to a sensor, in particular a temperature sensor, for use in a method, an apparatus, a space or a process unit according to the invention.

Further advantageous embodiments of a method, an apparatus and a space according to the invention are given in the subclaims. To explain the invention, practical examples thereof will be specified with reference to the drawings in which:

Fig. 1 diagrammatically shows, in cross-sectional side view, a ventilated space equipped according to present invention;

Fig. 2 diagrammatically shows a temperature distribution around a minimum temperature in a relative cold air stream, passed through a relative warm space;

Fig. 3 diagrammatically shows the position of a central line of an air stream with respect to temperature recording means of a sensor according to present invention;

Fig. 4 diagrammatically shows, in cross-section, an alternative embodiment of a ventilated space, a stable in the embodiment shown, according to present invention;

Fig. 5 diagrammatically shows a test arrangement for testing an apparatus according to present invention;

Fig. 6 diagrammatically shows the relation between the inclination of the central line calculated with a test arrangement according to Fig. 5 and with an apparatus according to present invention; and

Fig. 7 diagrammatically shows a diagram of an apparatus according to present invention;

Fig. 8 diagrammatically shows an alternative embodiment of an apparatus according to present invention, for mixing liquids;

Fig. 9 shows a further alternative embodiment of an apparatus according to present invention for mixing a gas into a liquid;

Fig. 10 shows a further alternative embodiment of an apparatus according to the invention, using a contactless measuring device; and

Fig. 11 shows an alternative arrangement of sensors, at least measuring points along a curved line, with an air pattern measured therewith.

In this specification similar or corresponding parts have similar or corresponding reference numerals. As an example of a space, this specification describes a stable, for instance, intended for keeping pigs, cows, chickens or the like, but it will be clear that an apparatus according to present invention is suitable for use in all kinds of spaces, for instance also living or office spaces,

storing spaces, spaces in transport means and the like. The practical examples shown should in no way be regarded as limitative.

Fig. 1 diagrammatically shows, in cross-sectional side view, a ventilated space, such as a stable 1, comprising a floor 2, outer walls 3, a roof 4 and a partition wall 5. Provided in the roof 4 is an air outlet 6, in this embodiment comprising a valve 7, arranged to at least completely or partly release the passage of the air outlet 6, and a ventilator 8 for sucking air from the inner space 9 of the stable 1 through the air outlet 6. Instead of or besides the ventilator 8 a throughput sensor may be provided for measuring the throughput flowing through the air outlet 6. Such a throughput meter is, for instance, described in Dutch patent application No. 9401632, which is deemed to be inserted herein by reference. Provided in the partition wall 5 is an air inlet 10 at a relatively great height above the floor 2, in which a second valve 11 is provided, so as to be able to release of the air inlet 10 at least completely or partly, as well as a (second) throughput sensor 12, for instance of the above-mentioned type, for measuring the air throughput flowing the air inlet 10. Here, too, besides or instead of the (second) throughput sensor 12 a ventilator may be provided to blow optionally conditioned air into the inner space 9. Near the end of the air inlet 10 directed to the inner space 9, air guide means 13 are arranged, in the drawing in the form of hinged plates, with which the outflow direction of a gas stream from the air inlet 10 to the inner space 9 can be adjusted. As an example, an alternative position for each air guide means 13 is shown in broken lines. Of course, all kinds of different air guide means may be used therefor, if necessary.

In the inner space 9 of the stable 1 animals are kept, symbolically represented by a pig 14. By providing in the inner space 9 a good regulation of at least the air streams extending therein, the climate control in the inner space 9 for living organisms, such as pigs 14, can be optimally regulated. This has a very positive effect on the living conditions for animals, plants or men

present therein and, thus, on the economic value and the well-being of the animals. Moreover, this is advantageous in terms of environment and energy.

For the regulation of the inner climate in the inner space 9 of the building 1 an apparatus is used according to the invention, which comprises at least one first sensor 15, coupled to a central process unit, in particular a control unit, such as a computer 16, in which an algorithm to be specified below is provided for the calculation, at least estimation of the position of a central line of an air stream 18 extending from the air inlet 10 into the inner space 9. The central line 17 is determined by a curve drawn through the points in the air stream with the minimum or maximum temperature in each relevant vertical cross-section through the air stream, perpendicular to the flow direction of the air in the relevant air stream. Whether the minimum temperature or the maximum temperature is applicable, depends on the temperature of the air stream with respect to the ambient temperature in the building 1. If the temperature of the air stream, at least when entering through the air inlet 10, is higher than the ambient temperature, the starting-point will be the maximum temperature for the position of the central line 17 of the air stream 18, while the starting-point will be the minimum temperature in the air stream 18 when the temperature of the inflowing air is lower than the ambient temperature in the inner space 9 of the building 1. In stables 1 and such spaces, the latter situation will be usual, so that in this further specification the starting-point will be the position of the central line at the level of the minimum temperatures in the above cross-sections. Other situations will be immediately clear to those skilled in the art.

The first sensor 15 comprises three temperature recording means T_1, T_2, T_3, placed at a fixed mutual distance S above each other, in a known position with respect to the floor 2 and the air inlet 10. The first sensor 15 is preferably placed such that the expected central line 17 extends between the upper temperature recording means T_1 and the lower temperature recording means T_3. This, however, is not necessary. The temperature recording means

are designed as thermometers which are at least resistant to moisture, dust and gases, such as usually present in a building 1, at least in a space in which the apparatus is to be used. The temperature recording means T_1, T_2, T_3 are mounted on a common support 19, so that they can be easily placed.

Fig. 2 diagrammatically shows how the normal, expected temperature distribution in an air stream will be with respect to the above central line, in a cold air stream. Fig. 2 clearly shows that an air stream has a practically symmetric, exponential temperature distribution. To base this distribution on theory, reference is made to, inter alia, Malmstrom et al, 1992 and formula 2.

Fig. 3A shows, at the level of the first sensor 15, a temperature curve C, fitted over the temperatures measured with respectively the first temperature recording means T_1, the second temperature recording means T_2 and the third temperature recording means T_3, while the temperature, for instance in degrees Celsius, is given on the vertical axis and the vertical distance below the middle of the air inlet 10 is given on the horizontal axis. The mutual distance S between the temperature recording means T_1, T_2 and T_3 is always the same, as indicated above.

Drawing the curve C through the points T_1, T_2 and T_3 immediately gives the position of the dip T_{min} of the curve C, comparable with the minimum shown in Fig. 2. T_{min} is at a distance D below T_2, as directly derivable from Fig. 3A.

Fig. 3B diagrammatically shows, in side view, the air inlet 10, the first sensor 15 with the temperature recording means T_1, T_2 and T_3 and, drawn therein, the distance D derivable from Fig. 3A, through which the point T_{min} with the minimum temperature can be directly drawn at the level of the first sensor 15. Subsequently, the central line 17 can be drawn, which extends through at least the middle and from the inlet 10 and the relevant point T_{min}. In this example, this central line will be slightly curved to below.

The form of the central line can be determined on the basis of models from the literature, for instance Randall, 1975; Randall 1981, Regenscheit,

1995; Mullejans, 1966; Boon, 1978; Randall & Battams, 1979; Holmes, 1974, using measurements of the air throughput, the inside temperature and the temperature of the incoming air, according to formula 1 as indicated below:

$$\gamma_x = \beta . a^{n} . \frac{(T_r - T_o)}{T_r . V^2} . x^{x} \qquad (1)$$

wherein Y_x: vertical deviation of the initial direction at distance x(m)

a : vertical inlet dimension (m)

T_r : average space temperature (K)

T_o : inlet temperature (K)

V : ventilation throughput (m^3/s)

x : horizontal distance with respect to the inlet (m)

β : parameter function of the space dimensions

η : real number between 1 and 3

α : real number between 2 and 3

This leads, for instance, to:

$$\gamma_x = (0{,}0585 * g * a^{1.5} * b^{1.5} * (T_r - T_o) * x^3)/(v^2 * T_r),$$

Theoretical values for the Archimedes number are given in the Table 1 below, as found in different literature references.

Subsequently, Table 2 gives an estimation for free-flowing fluids, starting from the Archimedes number, according to a number of references for the magnitudes in formula 2, on the basis of which the flow pattern can be estimated.

Table 1

Air jet trajectory	$\frac{y}{d_1} = K.Ar.\frac{x^\alpha}{d_2^\beta}$					
Author	K	d_1	d_2	Ar	α	β
Koestel (1955)	0.065	d_o	d_o	Ar_{Abr}	3	3
Regenscheit (1959)	$0.4\sqrt{m}$	a	a	Ar_{Reg}	2.5	2.5
Abramovich (1960)	0.052	d_o	d_o	Ar_{Abr}	3	3
Katz (1966)	0.17	1	d	Ar_{Kat}	2	3
Jackman (1970)	0.04	$\sqrt{A}$	B.H(B+H)	Ar_{Reg}	3	1
Holmes (1974)	0.0585	$\sqrt{A}$	$\sqrt{A}$	Ar_{Hol}	3	3
Walker (1974)	0.2	$\sqrt{A}$	$\sqrt{A}$	Ar_{Hol}	2.44	2.44
Kato, Murakami (1988)	0.42/K	d_o	d_o	Ar_{Mura}	3	3
Berckmans (1993b)	$0.4\sqrt{m}$	a	2.73+a/2	Ar_{ber}+0.45	3.3	2.5

Table 2

Archimedes Number	$Ar = \frac{g.l_c.(T_c - T_o)}{v^2.T_c}$		
author	T_c	l_c	v
Regenscheit (1959)	T_r	a	$\frac{V}{a.b}$
Abramovich (1960)	T_r	$\frac{2ab}{a+b}$	$\frac{V}{a.b}$
Müllejans (1966)	T_{hs}	$\frac{2.B.H}{B+H}$	$\frac{V}{B.H}$
Katz & Wittekindt (1966)	T_r	$1.27.\sqrt[3]{\frac{(a.b)^3}{a+b}}$	$\frac{V}{a.b}$
Holmes (1974)	T_r	$\sqrt{a.b}$	$\frac{V}{a.b}$
Croome, Gale & Roberts (1975)	T_r	H	$\frac{V}{a.b}$
Randall (1979)	T_{hs}	$\frac{2.B.H}{B+H}$	$\frac{V}{B.H}$
Nielsen et al.(1979)	T_r	a	$\frac{V}{a.b}$
Croome, Xi Li (1987)	T_r	$\frac{2ab}{a+b}$	$\frac{V}{a.b}$
Kato, Murakami (1988)	T_r	H	$\frac{V}{a.b}$
Sandberg (1992)	T_r	a	$\frac{V}{a.b}$
Berckmans (1993b)	T_{hs}	H	$\frac{V}{a.b}$

Table 2: Literature overview of the two-dimensional equations of a free air jet trajectory. The indicated Ar-values refer to table 4.1 (Kwanten, 1993).

With:

α, β	Variable parameters given in table 4.2
Ar	Archimedes number
a	Vertical dimension of air inlet (m)
A	Inlet section (m^2)
b	Horizontal dimension of air inlet (m)
B	Room width (m)
d_o	Inlet hydraulic diameter (m)
d_e	Effective hydraulic diameter of the inlet (m)
d_1	Inlet dimension according to table 4.2
d_2	Inlet dimension according to table 4.2
g	Gravitational acceleration (m/s^2)
H	Average room height (m)
l_c	Characteristic room dimension (m)
m	Turbulence factor (kg/s)
T_c	Characteristic room temperature (K)
T_r, t_i	Room temperature (K, °C)
T_o, t_o	Outside temperature (K, °C)
T_{hs}	Temperature of heated surface (K)
V	ventilation rate (m^3/s)
v	Air velocity (m/s)
Vol	Volume of the ventilated space (m^3)
y	Vertical deviation of initial horizontal stream direction (m)

The temperature distribution in the cold air stream can, according to Mahlström, 1992, be given according to formula 3, as indicated below:

$$\frac{\Delta t}{\Delta tx} = \exp(\sigma.\ln 2.\eta^2) \qquad (3)$$

with:

t : the temperature in a point γ (K)

t_x : the temperature on the center line at distance x of the inlet (K)

t_r : the average space temperature (°C)

Δt : $t - t_r$ (°C)

Δt_x: $t_x - t_r$ (°C)

η : $r/r_{0,5}$

r : radial distance to the center line (m)

$r_{0.5}$: r for the point where the velocity is half of the velocity on the center line.

With these two formulas the position of the central line of the flow pattern of the air stream 18 as well as the temperature distribution around it in the relevant air stream 18 can therefore be estimated very accurately.

Fig. 5 diagrammatically shows a test arrangement, specified by Derckmans D., Van de Weyer K., De Moor M., 1993. Visualization and quantification of the air flow pattern using image analysis, in: "Building Design, Technology and Occupant Well-Being" by Sterling E., Bieva C., Collett C., February 1993, publication by the American Society of Heating, Refrigerating and Air-Condition Engineers, pp. 207-216; with which by means of smoke a flow pattern in a test space can be determined. In this test arrangement an air inlet 10a is provided in a side wall of a test space, through which smoke is brought into the test space 9a. The smoke 18a, which

simulates the air stream 18, is lighted by means of a lamp 20 or laser and recorded with a video camera 21, after which by means of a suitable algorithm the position of the central line is determined in a computer 22. In Fig. 6 the thus determined central line is diagrammatically shown by the line 17a drawn between the diabolo-shaped points, while the central line 17 determined by means of an apparatus according to present invention is also drawn in Fig. 6, between points represented by asterisks. It clearly appears that only a minimum deviation occurs. By means of one first sensor 15 and measurement of the above-mentioned parameters (formulas 1, 2) the position of the central line 17 and the temperature distribution in the air stream can therefore be estimated accurately.

It is of course also possible to place a series of first sensors 15 after each other in the air stream 18, as diagrammatically shown in Fig. 4. Preferably, the first sensors 15A, 15B, 15C are then placed at mutual distances F after each other, such that a matrix of temperature recording means T_1 (A,B,C), T_2 (A,B,C), T_3 (A,B,C) is obtained. Thus an estimation of the position of the central line 17 of the air stream 18 can be directly obtained by drawing a curve through the points T_{min} (A,B,C), obtained as described before, at the respective first sensors 15A, 15B, 15C. Of course, the above-mentioned formulas can then be used as well, but this is not necessary.

Fig. 4A shows a further alternative embodiment of a first temperature sensor 115, in particular suitable for three-dimensional determination of the fluid flow for non-free fluids flow, while on a support 119, for instance, a wire frame for each first sensor 115 a three-by-three matrix of temperature regulating means T is arranged, which can be designated by $T_{1,1}$ ... $T_{3,3}$. With such first temperature sensors 115 a three-dimensional image of an air stream 118 can be estimated, since therewith, for instance with respect to the position of the middle temperature recording means $T_{2,2}$ the vertical distance D_1 and the horizontal distance D_2 to the minimum temperature T_{min} in the plane of the support 119 in the air stream 118 can be determined. The

temperature distribution in the air stream 18 with respect to this central line 117 can again be determined, at least estimated with the above-mentioned formula 2 or by a good fitting when using several sensors.

Fig. 7 diagrammatically shows a regulating device 30 according to the invention, in an advantageous embodiment. This regulating device 30 comprises the process unit 16, which comprises a calculating unit 16a and a data bank 16b, which can communicate with each other. Moreover, a display 26 and a keyboard 27 or such apparatus is provided for respectively displaying and inputting data. For this part of the regulating device 30 a computer or the like can of course be used. Provided in the calculating unit 16a is an algorithm into which data can be inputted from the or each first sensor 15 (A-C), a second temperature sensor 23 placed in the air inlet 10 and/or a third temperature sensor 24 placed in the air outlet 24. Moreover, data are inputted to the calculating unit 16a about the position of the air guide means 13, the second valve 11 and the first valve 7, while data are also inputted from the ventilator or throughput sensor 12 and the throughput sensor or ventilator 8 in respectively the air inlet 10 and the air outlet 6, if present. Moreover, further recording means 25 can be connected to the calculating unit, for instance for measuring the ambient temperature inside and outside the space, air humidity and the like, which can be used in the algorithm. It will be clear that the different data will only be available when the different recording means are present.

In the calculating unit 16a the actual flow pattern of the air stream 18 is determined by means of the above algorithm, which can be compared with profiles stored in the data bank 16b. On the basis of this comparison and, if required, further conditions to be inputted via the keyboard, subsequently, if present, the air guide means 13, the first valve 7 and the second valve 11 and optionally ventilators 12 or 8, and other air inlet regulating means and/or air outlet regulating means and the like, can then be controlled, as well as, for instance, air humidifiers, heating means, cooling means and the like.

Selections thereof, depending on the space in which climate control is to be carried out, will be immediately clear to those skilled in the art.

Fig. 8 diagrammatically shows, in cross-sectional side view, a container 230 for a first liquid 231, for instance paint, which container 230 is provided with a inlet opening 232 through which a stream of second liquid 233 can be supplied to the container 230. Fig. 8 diagrammatically shows the center line 218 of the stream 230. As shown, the container 230 has three sensors 215a, 215b, 215c, placed at a regular distance F from each other. Each sensor 215 comprises three flow sensors R1, R2, R3, arranged at a fixed mutual distance S above each other. By means of the matrix of flow recording means, such as flow sensors, the centerline 218 of the stream of second liquid 233 in the container 230 can be determined and can be compared with a desired flow, for instance by means of a regulating device, comparable with the regulating device shown in Fig. 7. Optionally, mixing means 234 can be provided in the container 230, for instance in the form of a stirrer, with which the flow pattern can be influenced, which influencing can again be recorded by means of the sensors 215. It will be clear that thus for all kinds of different liquids and combinations of liquids flow patterns can be determined and are influenced to obtain an optimum flow pattern and, for instance, an optimum mixing between two or more liquids.

Fig. 9 diagrammatically shows, in cross-sectional side view, an aeration tank 330 for, for instance, waste water 331, in which aeration tank 330 a central column 340 is arranged, which is provided with, for instance, four aeration tubes 342 forming a cross and extending horizontally near the bottom 341. By means of pumping means 343 air can be forced through the aeration tubes 342 and can be pressed out through the openings provided therein, into the waste water 331. The air will show a flow pattern of air bubbles, diagrammatically represented by broken lines 318. In the aeration tank 330 a grid of sensors 315a-315d is arranged to the left and 315e-315h to the right of the central column 340, at least in the embodiment shown in

Fig. 9. The sensors 315 shown to the left and to the right are only given as practical examples. Each sensor 315 comprises, for instance, three density recording means spaced apart at a fixed distance S, with which, again, the central line 318 of the air flows can be determined. This offers the advantage that, for instance, the rotational speed of the aeration arms can be easily regulated, so as to obtain an optimum distribution of air in the water. To this end, a circular pattern of sensors 315 is preferably arranged concentrically around the central column. It will be clear from Fig. 9 that sensors can be arranged in a container for liquid in a different manner, so as to determine flow patterns of gases therein. In particular when in Figs. 8 and 9 reference is made to a container or tank, this should be broadly interpreted. In natural and semi-natural liquid areas too, such as lakes and the like, sensors can be used according to the invention.

Fig. 10 diagrammatically shows a part of a further alternative embodiment of an apparatus according to the invention, using a contactless measuring device 415, 415X. In this embodiment a series of loudspeakers 415X_1-X_3 is arranged at a first side of a space, a series of microphones 415A-C is arranged at a second side, such that between them the desired values of a magnitude, for instance air temperature, velocity, humidity or the like can be measured. By means of tomographic algorithms, for instance the temperature at all points between the microphones and loudspeakers can be measured. Fig. 10 shows five such points T_1-T_5. By means of a central control unit 416 the loudspeakers 415X_1-X_3 are controlled for transmitting an acoustic signal, which signals can be received by the microphones 415A-C. On the basis of the occurring changes in the sound signals a desired magnitude can be measured, at least determined, for instance in the above points T_1-T_5, without the microphones and/or loudspeakers (which are comparable with the sensors described before) coming into contact with an air stream. Such a measuring method, at least the use of acoustic measuring means, is described per se in the later published international patent application WO 99/NL00386, which

application is deemed to be inserted herein by reference. It will be clear that with the measuring values obtained by means of the central control unit 416, in a manner as described before, for instance the position of the central line 417, symbolically represented by a point, can be determined or the position of a point with, for instance, a specific temperature. In a comparable manner other sources and receivers for (electro)magnetic waves can be used as well. Moreover, sensors at least partly placed in a fluid stream can be used, which can be read out contactlessly at a distance. The advantage of using contactless measuring means is that through them the normal use of a space in which these means are arranged, at least used, is even less impeded, while yet air flows can be determined accurately, on the basis of which, for instance, regulations are possible, while negative influencing of the measuring device by, for instance, gases and liquids can be prevented even better.

Fig. 11 diagrammatically shows a further alternative arrangement of sensors 15, in which the or each first sensor 15 comprises a series of temperature recording means T_1-T_{13} arranged on a curved line L, in particular an arc. In the embodiment shown, an arc-shaped line L is selected with the middle of the air inlet 10 as middle point. The mutual distance between the temperature sensors T_n and $T_{(n+1)}$ is again S, determined by the angle α enclosed between both sensors T, seen from the above middle point. Again, in the manner described before, the position of the maximum or minimum temperature at least on the line L can be determined therewith, so that the position of the central line 17 can be determined. Fig. 11, at the top, diagrammatically shows an air pattern 18, measured with an apparatus according to Fig. 11, shown at the bottom, in which air pattern 18, at the level of the arrow K, a profile of air flow velocities is shown. Drawn in Fig. 11 are the angle θ_0 which the main direction of movement of the air stream at the level of the inlet 10 encloses with the horizontal and the angle θ, determined by a line through the above middle point and the intersection point of the line L with the central line 17. This intersection point is denoted by B(x,y).

The invention is in no way limited to the practical examples shown in the specification and the figures. Many variations thereof are possible within the scope of the invention described by the claims.

Thus, several first temperature sensors may be provided, while, moreover, the or each first temperature sensor of more or fewer temperature recording means may be provided. When using two temperature recording means per temperature sensor, use will have to be made of the estimated local minimum or maximum air temperature in the air stream, at the level of the relevant temperature sensor. Furthermore, a space can be provided with several air inlets and/or air outlets. For each air stream the flow pattern may then be determined in the manner described before, while mutual temperature influencing can be taken into account. Furthermore, with a regulating device according to present invention advance control can be effected on the basis of a flow pattern determined therewith and previously known factors influencing the climate control, so as to enable rapid anticipation of changing conditions, for instance when other animals are brought into the stable 1 or are led away therefrom. Moreover, other formulas may be used to estimate the curves through the different points with minimum or maximum temperature, that is to say to estimate the position of the central line of the relevant air stream. It will be clear that an improvement of the accuracy of this estimation will enable a more accurate regulation. For the rest, it will be clear that, where in this specification sensors are shown, the described contactless measuring methods may also be used in principle.

These and comparable variations are deemed to fall within the scope of the invention described by the claims.

Literature references

Boon, C.R. (1978). Airflow Patterns and Temperature distribution in an experimental Piggery. J. Agric. Engng.Res., vol.23. p.129-139.

Holmes M.J. (1974). Internal flow aspects and circuit design of heating and ventilation systems. Von Karman Institute for fluid dynamics, 15 pp.

Malmstrom, T., & Hassani, V. (1992). Use of constant momentum for supply of cold air. Roomvent '92, Third International Conference, Aalborg, Denmark, September 2-4, 1992, Publisher:DANVAK, Lyngby, Denmark, Vol. 3, pp.125-140.

Mullejans H. (1966). Über die Ähnlichkeit der nicht-isothermen Strömung und den Wärmeubergängen in Räumen mit Strahllüftung.

Randall, J.M. (1975). The prediction of Airflow Patterns in Livestock Buildings. J. Agric Engng.Res., vol.20, p.119-215.

Randall, J.M. (1981). Ventilation system design. In Environmental aspects of housing for animal production, ed. J.A. Clark, Butterworths, London., pp.351-369.

Randall, J.M. & Battams, V.A. (1979). Stability Criteria for Airflow Patterns in Livestock Buildings. J. Agric. Engng.Res., vol24. p.361-374.

Regenscheit, B. (1959). Air movement in air-conditioned rooms (Die Luftbewegung in klimatisierten Räumen). Kältetechnik, vol.11. pp.3-11.

Claims

1. A method for determining a flow pattern of a fluid in a space, wherein:

- a fluid is passed via at least one inlet into the space,
- in a first position, at a distance from the at least one inlet, a distribution of a fluid magnitude, at least a similar magnitude is measured at least twice and preferably at least thrice at a mutual distance in at least a part of the fluid stream,
- determining, on the basis of the measured distribution, at least in respect of the measured magnitude, the position of the maximum or minimum value of the relevant magnitude, and
- determining, on the basis of at least the position of this maximum or minimum value, the flow pattern in the space, preferably by means of an algorithm.

2. A method according to claim 1, wherein at least in or near the or each inlet the fluid throughput is measured.

3. A method according to claim 1 of 2, wherein in or near the at least one inlet the inflow direction of the fluid is determined.

4. A method according to any one of the preceding claims, wherein in or near the at least one inlet the relevant magnitude of the fluid is measured, wherein preferably, moreover, at a distance from the fluid stream a comparable magnitude in the space is determined.

5. A method according to any one of the preceding claims, wherein in the fluid stream in said first position at least two, preferably at least three recording elements for the relevant magnitude are arranged at a distance from each other, in particular above each other, for measuring the local value of the relevant magnitude, wherein on the basis of the value differences the position of the maximum or minimum value in said first position is determined.

6. A method according to any one of the preceding claims, wherein said fluid magnitude is measured contactlessly, preferably acoustically.

7. A method according to any one of the preceding claims, wherein in at least two positions placed one after the other in the flow direction of the fluid stream the distribution, at any rate at least two values, are measured.

8. A method according to any one of the preceding claims, wherein on the basis of at least the flow pattern of the fluid stream the throughput of the at least one inlet is regulated and/or the direction of inflow of the fluid into, at least from the at least one inlet is regulated and/or at any rate a part of the fluid stream is passed from the space via at least one outlet, wherein in, at any rate near the at least one outlet the relevant magnitude of the fluid stream and preferably also the throughput and/or the composition thereof is measured.

9. A method according to any one of the preceding claims, wherein as fluid a gas is passed into a space and wherein as magnitude at least one of the following magnitudes is measured:

temperature, flow velocity, flow direction,
pressure, concentration of a component, density.

10. A method according to claims 9, wherein the gas is passed into a space substantially filled with gas.

11. A method according to claim 9, wherein the gas is passed into a space substantially filled with liquid or suspension.

12. A method according to any one of the preceding claims, wherein as fluid a liquid is passed into a space and wherein as magnitude is measured at least one of the following magnitudes is measured:

temperature, flow velocity, flow direction,
pressure, concentration, density.

13. A method according to claim 12, wherein the liquid is passed into a space substantially filled with liquid.

14. An apparatus for determining a flow pattern of a fluid in a space, comprising:

- at least one first measuring device, which first device can measure a magnitude in at least two and preferably at least three different positions, and
- a process unit to which the values of the measured magnitude can be passed,
- wherein the process unit is provided with an algorithm for determining, during the use on the basis of at least the measured values, the position of the maximum or minimum value of the relevant magnitude in the fluid stream at the level of the relevant first measuring device and, at least partly on the basis thereof, determining the flow pattern.

15. An apparatus according to claim 14, further comprising at least one second measuring device for the relevant magnitude, for positioning in or near a fluid inlet.

16. An apparatus according to claim 14 or 15, further comprising at least one throughput sensor for positioning in or near a fluid inlet or fluid outlet.

17. An apparatus according to any one of claims 13-16, wherein at least each first measuring device comprises at least one first sensor for the relevant magnitude, arranged for placement in a fluid stream.

18. An apparatus according to any one of claims 13-17, wherein at least each first measuring device is arranged for contactlessly measuring said magnitude, preferably acoustically.

19. An apparatus according to claim 17, wherein the or each first sensor comprises at least two and preferably three recording elements for the relevant magnitude placed at a mutually known distance, such that the recording elements are placeable for use substantially along a straight or curved line in the fluid stream, while a preferably regular pattern of recording elements in a space can be obtained with a series of first sensors.

20. An apparatus according to any one of claims 13-19, wherein the or each first measuring device is arranged to measure said magnitude in at least

two and preferably at least three positions on a straight or curved line, such that a preferably regular pattern of recordings can be obtained with a series of first measuring devices.

21. An apparatus according to any one of claims 13-20, wherein at least the or each first measuring device, the process unit and fluid inlet regulating means and/or fluid outlet regulating means are incorporated into a regulating cycle, in which during use the fluid inlet regulating means and/or fluid outlet regulating means provide data with respect to the fluid stream, which data are processed by the process unit, such that at least partly on the basis of these data the fluid inlet regulating means and/or fluid outlet regulating means are regulated.

22. An apparatus according to any one of claims 13-21, wherein the recording elements at least comprise temperature recording elements.

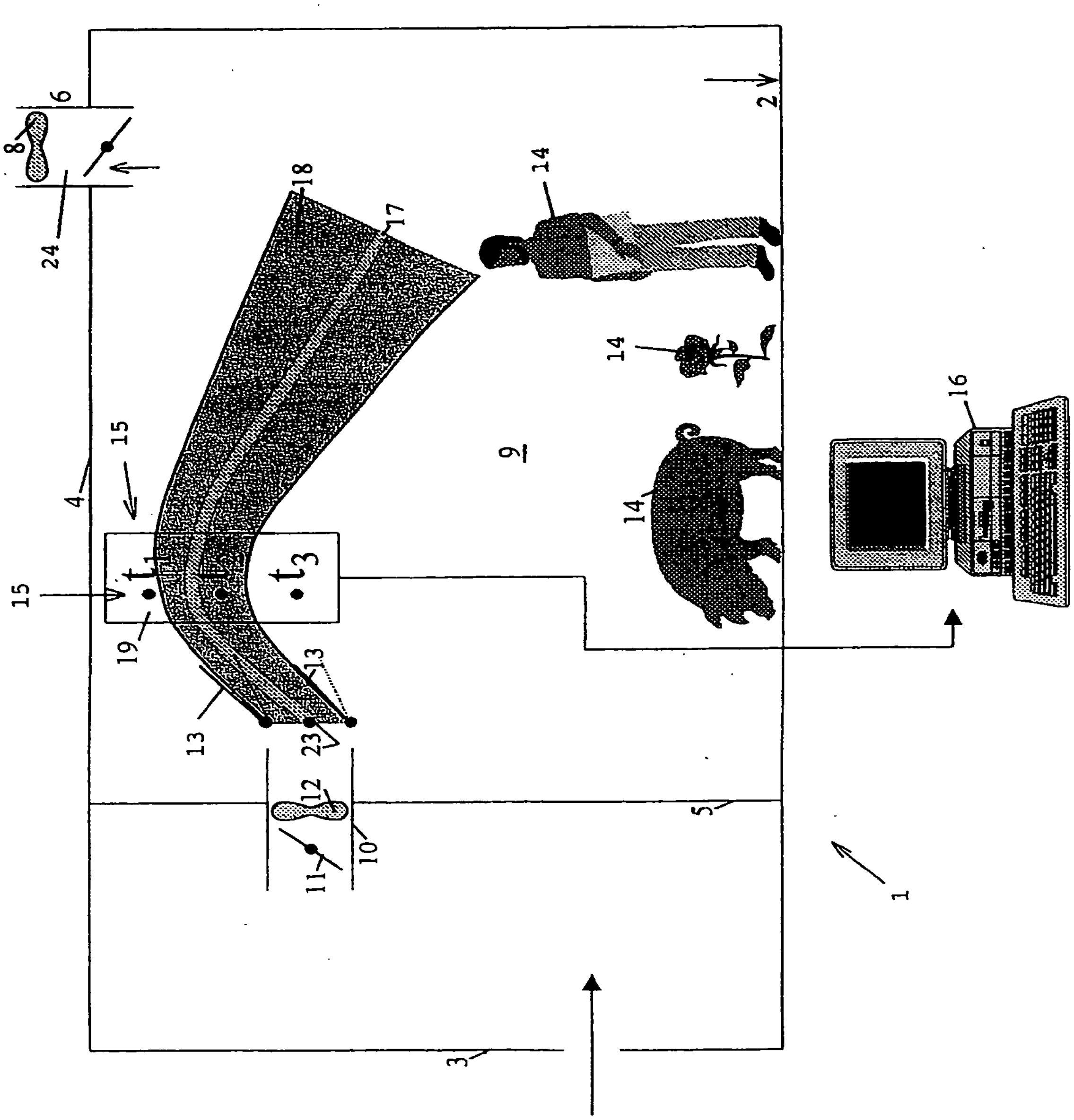
23. A space, provided with an apparatus according to any one of claims 13-22, wherein a preferably regular pattern of at least first sensors is provided, in particular recording elements thereof in at least a part of the space between at least one fluid inlet and at least one fluid outlet.

24. A space according to claim 23, wherein the at least one fluid inlet is provided relatively high in the space.

25. A process unit for use in a method according to any one of claims 1-13, in an apparatus according to any one of claims 14-22 or in a space according to any one of claims 23 or 24.

26. A sensor, in particular a temperature sensor for use in a method according to any one of claims 1-13, in an apparatus according to any one of claims 14-20, in a space according to any one of claims 23 or 24 or in a process unit according to claims 25.

FIG. 1



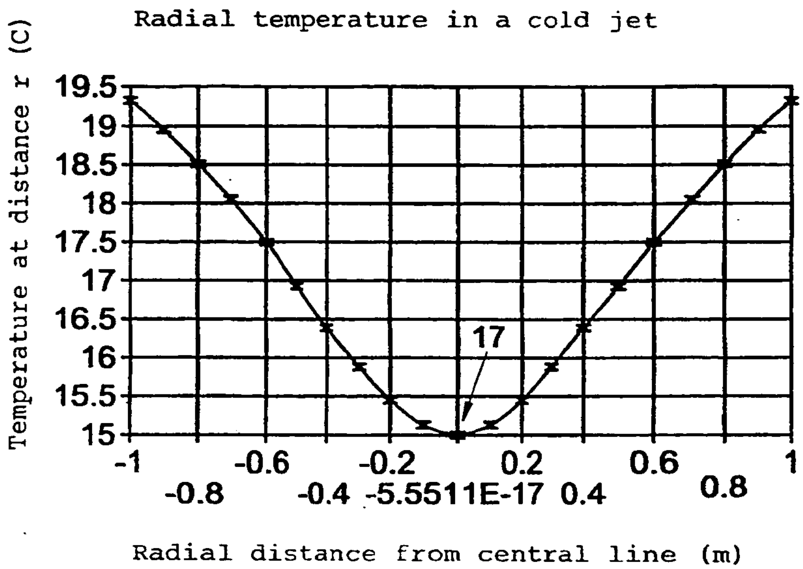

Radial temperature in a cold jet
Temperature at distance r (C)
19.5
19
18.5
18
17.5
17
16.5
16
15.5
15
17
-1
-0.8
-0.6
-0.4
-0.2
-5.5511E-17
0.2
0.4
0.6
0.8
1
Radial distance from central line (m)

Fig. 2

FIG. 3A

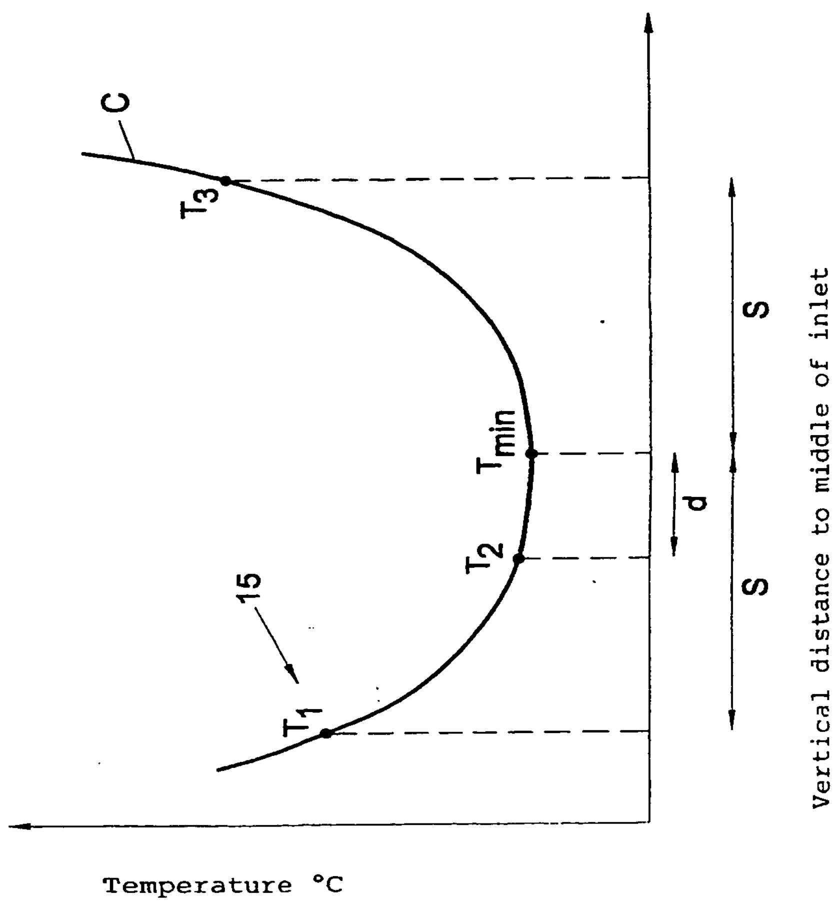

C
T_3
T_{min}
T_2
T_1
15
S
d
S
Vertical distance to middle of inlet
Temperature °C

FIG. 3B

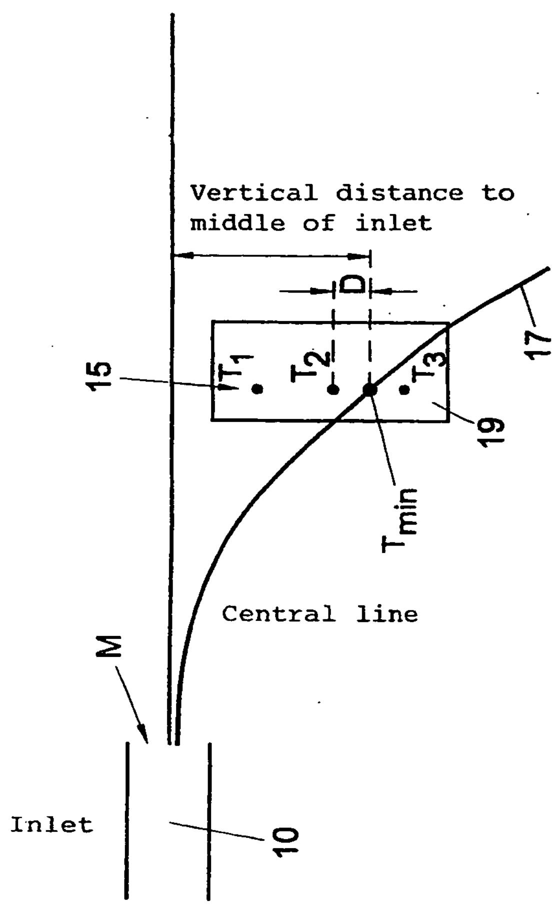

Vertical distance to
middle of inlet
D
15
T_1
T_2
T_3
17
19
T_{min}
Central line
M
Inlet
10

FIG. 4

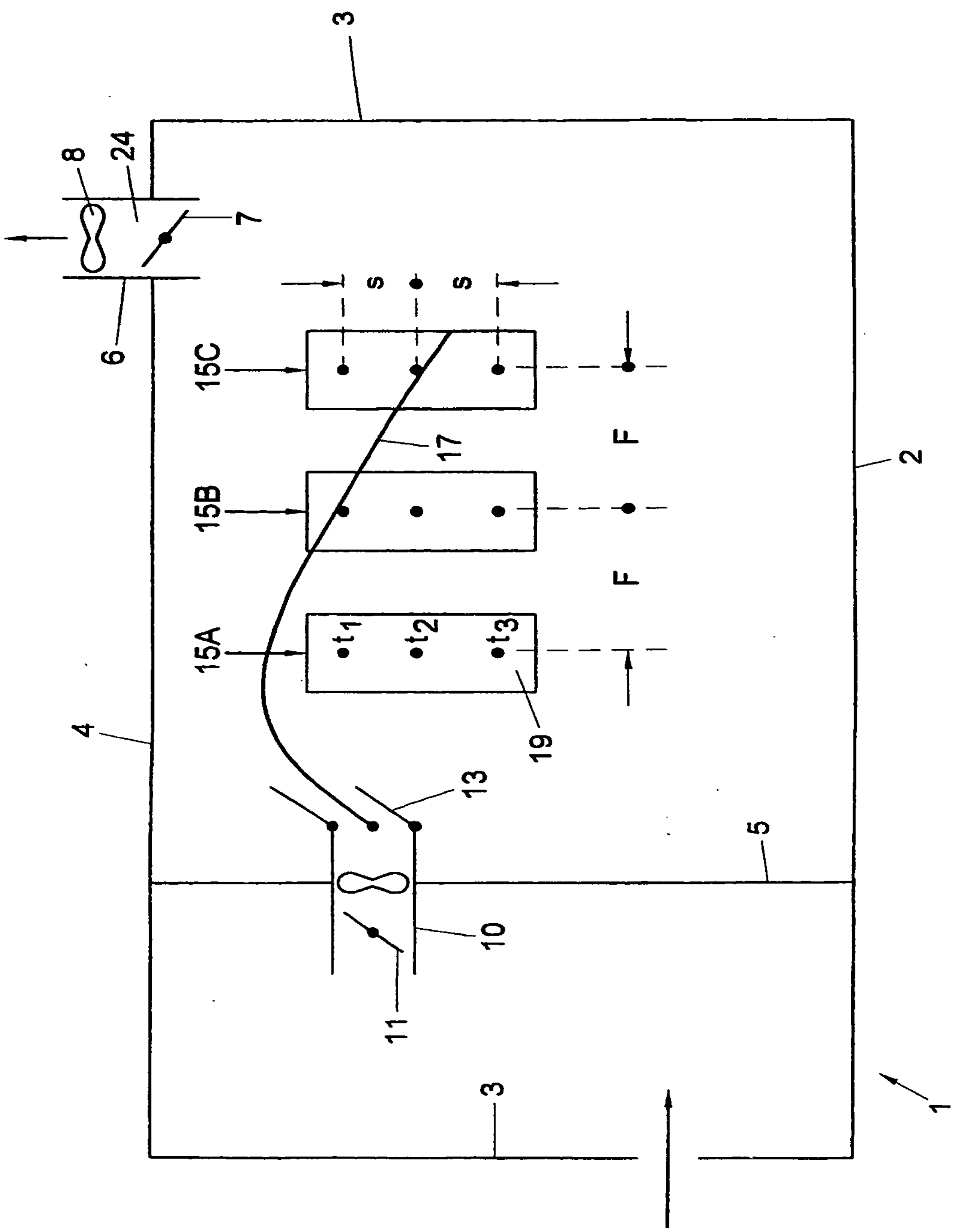
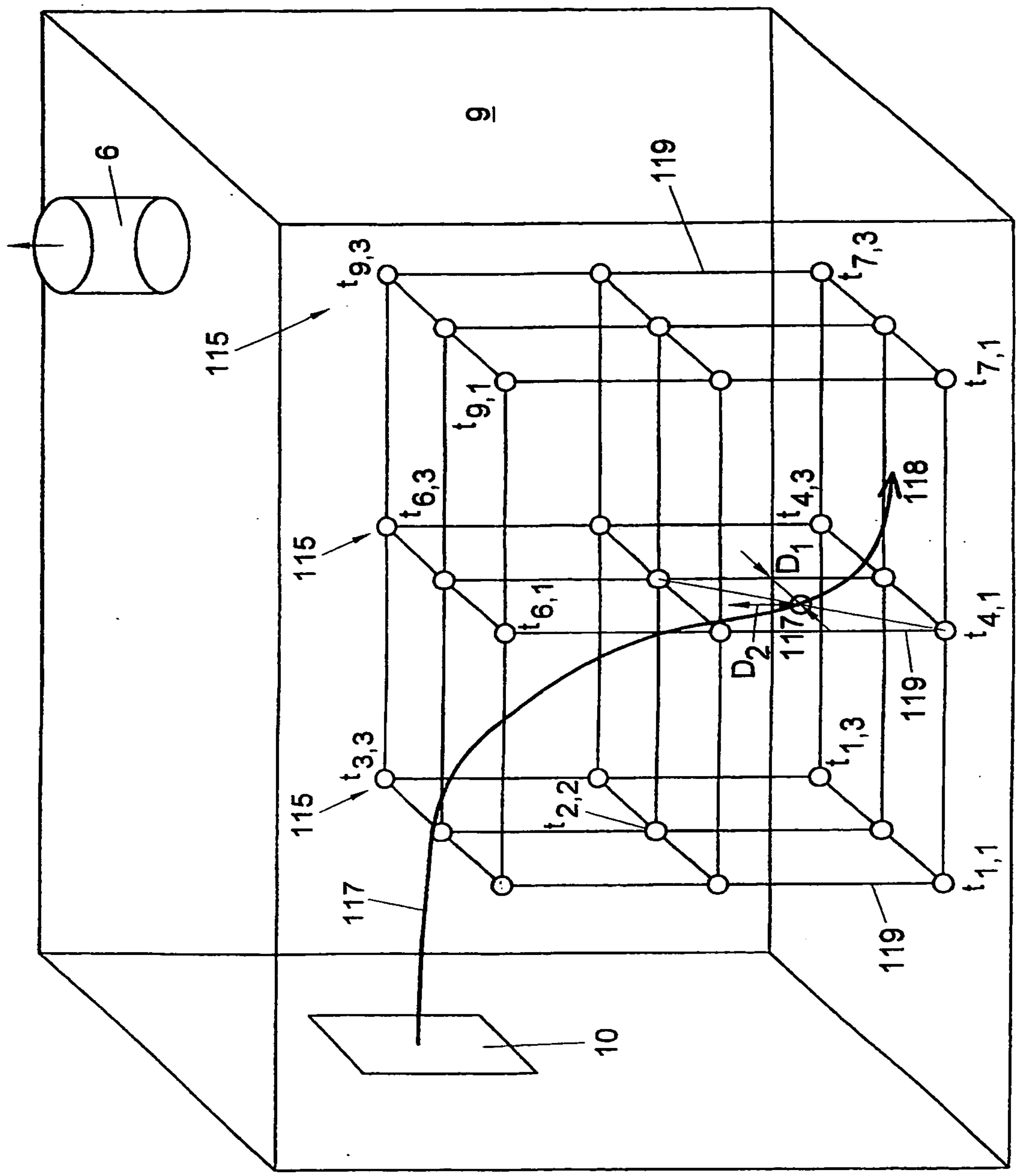


FIG. 4A


6
9
119
115
$t_{9,3}$
$t_{7,3}$
$t_{9,1}$
$t_{7,1}$
115
$t_{6,3}$
$t_{4,3}$
118
D_1
$t_{6,1}$
$t_{4,1}$
D_2
117
119
115
$t_{3,3}$
$t_{1,3}$
$t_{2,2}$
117
$t_{1,1}$
119
10

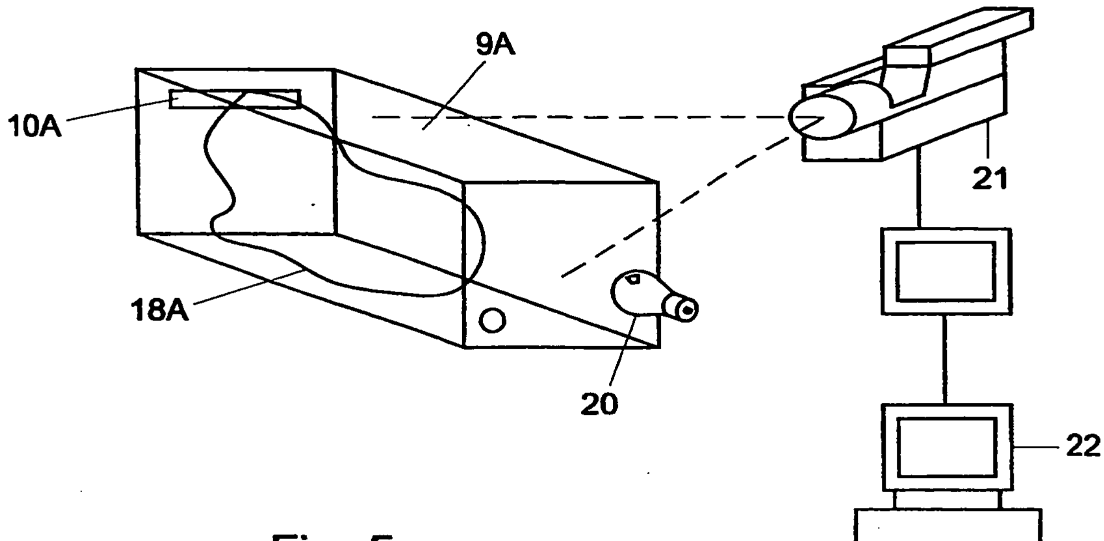

9A
10A
21
18A
20
22

Fig. 5

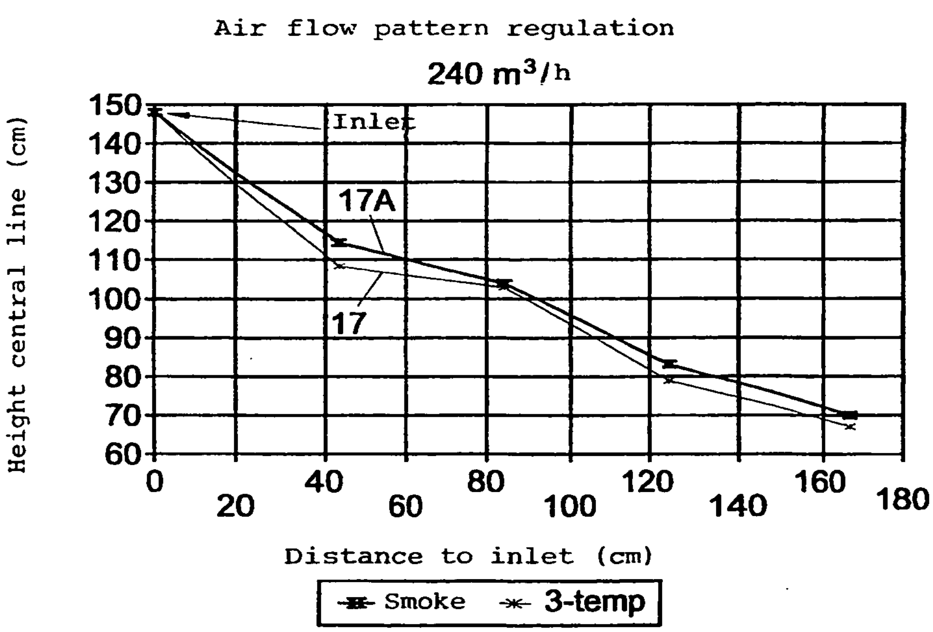

Air flow pattern regulation
240 m³/h
Height central line (cm)
150
140
130
120
110
100
90
80
70
60
Inlet
17A
17
0
20
40
60
80
100
120
140
160
180
Distance to inlet (cm)
Smoke
3-temp

Fig. 6

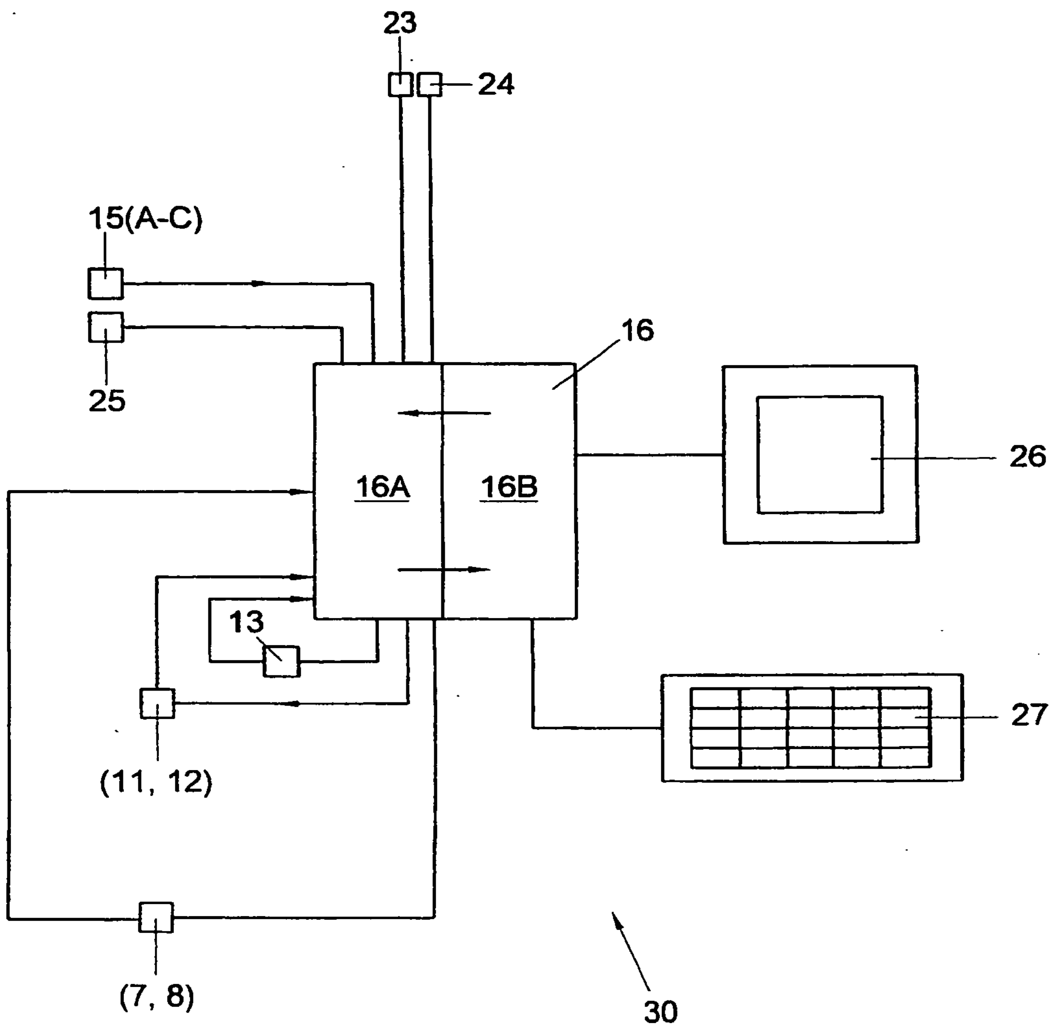


Fig. 7

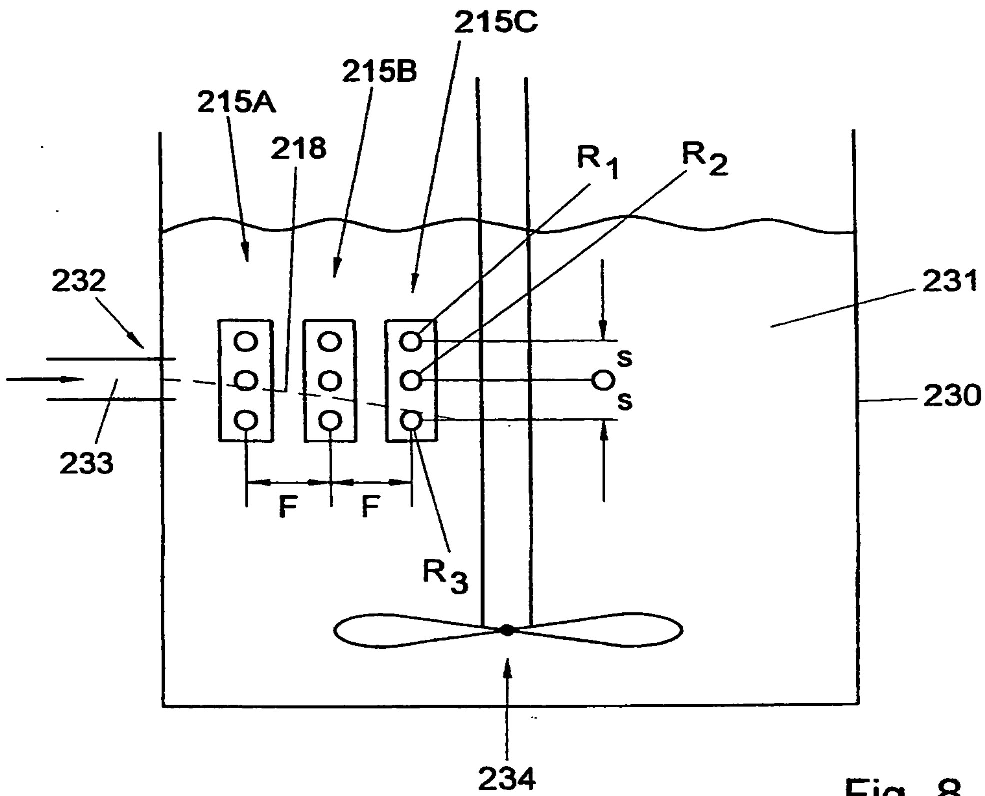

215C
215B
215A
218
R1
R2
232
231
s
s
230
233
F
F
R3
234

Fig. 8

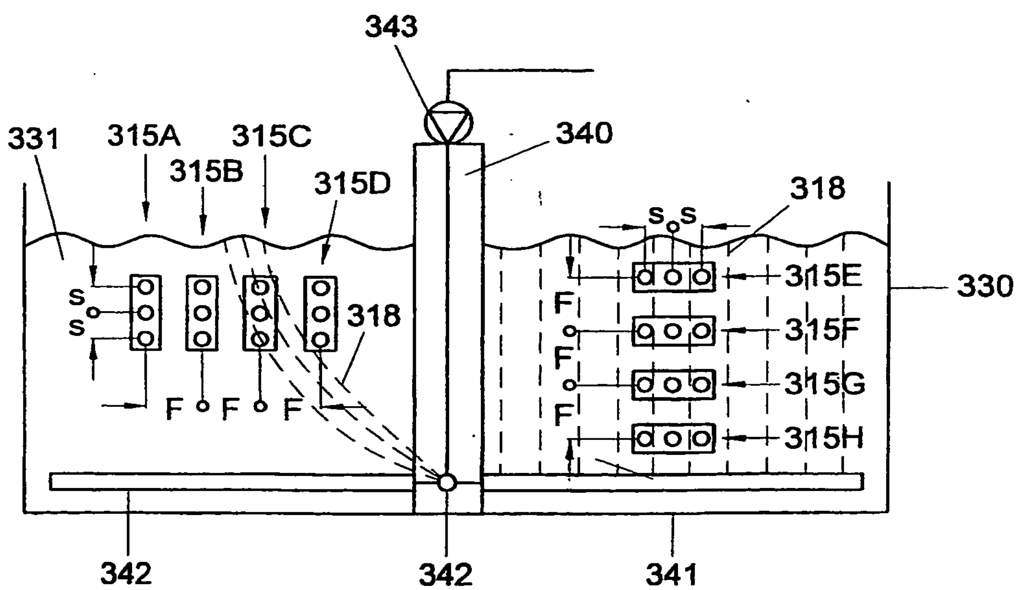

343
331
315A
315C
340
315B
315D
318
s
s
s
s
318
315E
330
F
315F
F
315G
F
F
F
F
315H
342
342
341

Fig. 9

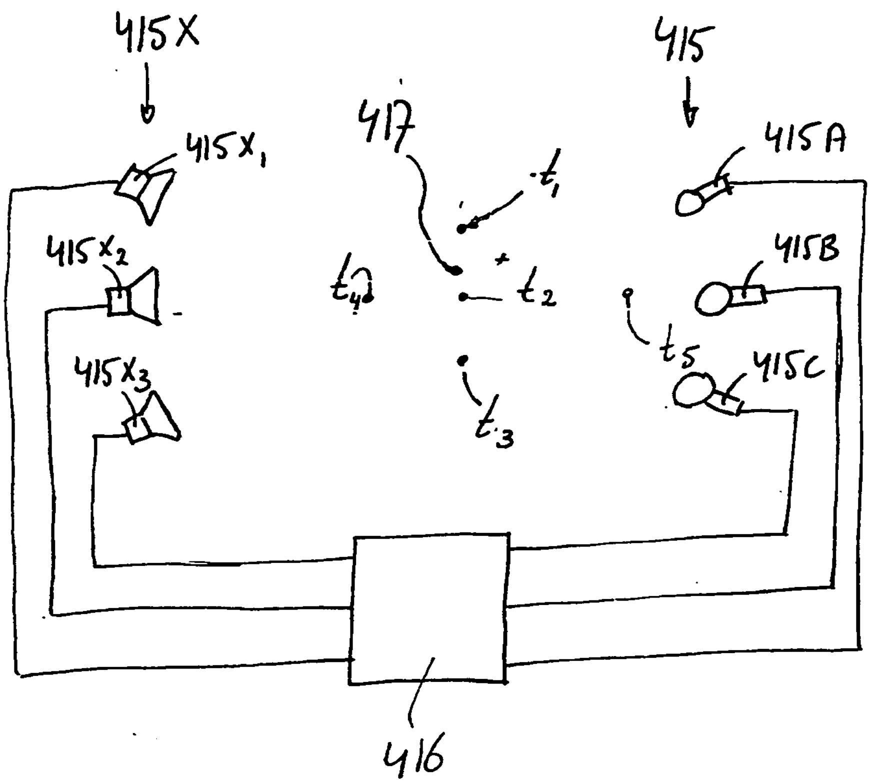
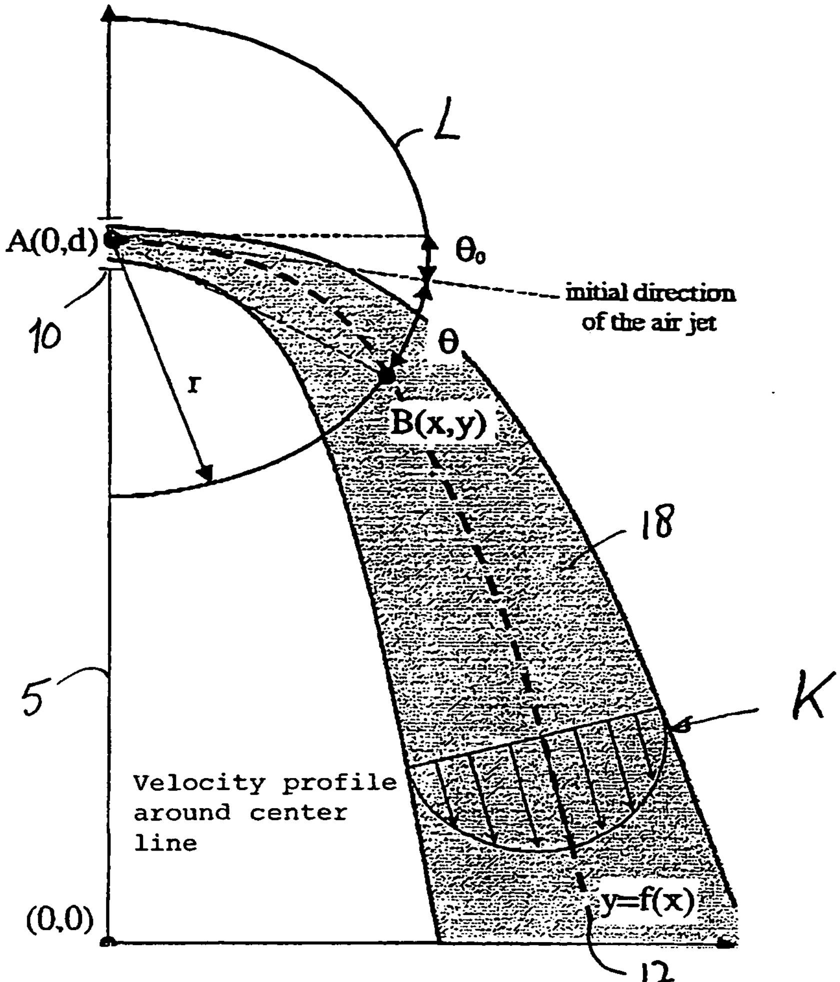
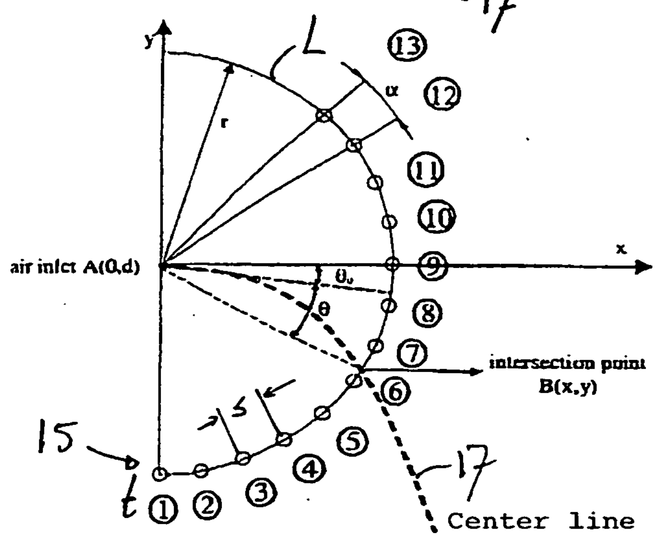

415X
415
415X1
417
t1
415A
415X2
t4
t2
415B
t5
415X3
415C
t3
416

FIG. 10





Air pattern sensor according to the axe principle consisting of 13 temperature sensors

FIG. 11

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference P11141PC00	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/IB 00/ 00865	International filing date *(day/month/year)* 28/06/2000	(Earliest) Priority Date *(day/month/year)* 28/06/1999
Applicant KATHOLIEKE UNIVERSITEIT LEUVEN et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.
   [ ] filed together with the international application in computer readable form.
   [ ] furnished subsequently to this Authority in written form.
   [ ] furnished subsequently to this Authority in computer readble form.
   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

   [ ] as suggested by the applicant.
   [X] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 00/00865

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01F1/68 A01K1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01F A01K F24F G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 171 117 A (SMULDERS ADRIANUS HENRIKUS JOS) 12 February 1986 (1986-02-12)	25,26
A	page 5, line 24 -page 6, line 19; figure 1	1-24

X	EP 0 643 272 A (SODALEC SA) 15 March 1995 (1995-03-15)	25,26
A	column 3, line 2 - line 21; figures 1-3	1-24

X	DE 41 27 179 A (GAEBKEN ELEKTROINSTALLATION GM) 18 February 1993 (1993-02-18)	25,26
A	the whole document	1-24

A	FR 2 732 098 A (SARL TUFFIGO) 27 September 1996 (1996-09-27) the whole document	1-24

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 November 2000	24/11/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Boerrigter, H

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB 00/00865

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0171117 A	12-02-1986	NL 8402389 A	17-02-1986
		AT 30367 T	15-11-1987
		DE 3560805 D	03-12-1987
		DK 342285 A	01-02-1986
		DK 342385 A	01-02-1986
		EP 0173374 A	05-03-1986
		NL 8403082 A	17-02-1986
EP 0643272 A	15-03-1995	FR 2710139 A	24-03-1995
DE 4127179 A	18-02-1993	NONE	
FR 2732098 A	27-09-1996	NONE	

1/4

PATENT COOPERATION TREATY

REC'D 10 OCT 2001
WIPO PCT

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P11141PC00	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/IB00/00865	International filing date *(day/month/year)* 28/06/2000	Priority date *(day/month/year)* 28/06/1999
International Patent Classification (IPC) or national classification and IPC G01F1/68		
Applicant KATHOLIEKE UNIVERSITEIT LEUVEN et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 6 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand 18/01/2001	Date of completion of this report 05.10.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Loades, M Telephone No. +49 89 2399 2184

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1,3-23	as originally filed			
2,2a	as received on	20/07/2001	with letter of	20/07/2001

Claims, No.:

1-21	as received on	19/09/2001	with letter of	19/09/2001

Drawings, sheets:

1/11-11/11	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-21
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-21
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-21
	No:	Claims	

2. Citations and explanations
   see separate sheet

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. The following documents are referred to in this report:

   D1: EP-A-0 171 117 (SMULDERS ADRIAN US HENRIKUS JOS) 12 February 1986 (1986-02-12)
   D2: EP-A-0 643 272 (SODALEC SA) 15 March 1995 (1995-03-15)
   D3: DE 41 27 179 A (GAEBKEN ELEKTROINSTALLATION GM) 18 February 1993 (1993-02-18)
   D4: FR-A-2 732 098 (SARL TUFFIGO) 27 September 1996 (1996-09-27)

2. **Review of the prior art documents:**

D1 relates to a system somewhat similar to that of the present application for environmental monitoring of a space. Two temperature sensors are horizontally spaced, across the space, the average of the signals therefrom being used to control an inlet valve 5 and outlet fan 7. It is also possible to have three sensors, two at equal distances from a central one, to provide further correction.

D2 relates to a system for controlling ventilation of a space, in which the outputs of a plurality of temperature sensors are supplied to a control unit. Col. 4, line 11 refers to the amount of ventilation required being a percentage of the maximum of a measured parameter.

D3 relates to a system for controlling ventilation of a space, in which the outputs of a plurality of temperature and other sensors are supplied to a control unit.

D4 relates to a further temperature controlled ventilation system.

3. Novelty and inventive step:

(The wording of claim 1 is not entirely clear as to the number of sensing elements in the sensor; the wording could conceivably include a single sensing element which is moved to the three fixed points in turn, although there is no disclosure of such an embodiment. However, it seems unlikely that the maximum or minimum value of the parameter distribution could be reliably obtained in such a system. Claim 1 is thus understood to mean using respective sensing elements at the three points to obtain the parameter values substantially simultaneously. Similarly , claim 14 is understood in that the wording "for measuring a parameter in at least three points spaced apart along a line", should in fact be a similar limiting feature of the claim, i.e. the wording should have been amended to e.g. "arranged to measure a parameter of said fluid at at least three respective points spaced apart along a line").

Claims 1 and 14
Although D2 contains a reference to a maximum value of a measured parameter, none of the cited documents refers to or hints at determining the position of the maximum or minimum of the measured parameter, in order to derive a flow pattern.
Thus claims 1,14 and claims 2-13, 15-21, dependent thereon, appear to be novel and inventive in relation to the prior art.

10/018699

531 Rec'd PC 12 DEC 2001

experience. It will be clear that, in general, no ideal adjustment will thus be obtained. Moreover, this can only be examined by measuring afterwards and not in situ.

Furthermore, when mixing via liquids, for instance in the preparation of paints and lacquers, foodstuffs, medicaments and the like, it is highly important that a complete mixing is obtained. Here, too, it has hitherto not been possible to measure in situ the flow pattern of a liquid stream passed into a tank or the like.

EP 0 171 117 discloses a system for maintaining a desired temperature in a stable, wherein the incoming and outgoing quantity of air is regulated using an inlet valve and a fan. The temperature is measured by two sensors, one close to the inlet valve and the other close to the fan. Both sensors are connected to a micro processor. This micro processor controls the inlet valve and/or the fan based on variations in the temperature differences and the average temperature measured in both sensors.

EP 0 643 272 discloses a climate control unit for a stable comprising a control unit for regulating a fan based on climate parameters such as temperature and humidity. One or more sensors can be provided for measurement of said parameters.

DE 41 27 179 also discloses a climate control unit for a stable in which humidity, temperature and the introduction of fresh air are controlled based on a control unit, a fan and a heating element. This publication does not disclose the sensors to be used.

FR 2 732 098 discloses a system for control of ventilation and heating of a poultry stable, in which the quantity of air to be displaced is controlled bases on the temperature and humidity of the stable and the age, weight and sex of the poultry. Displacement of said air is achieved by a series of fans to be controlled continuously, intermitted or in series.

From the prior art as discloses here above it is not known to determine a flow pattern of a fluid for control purposes.

It is an object of the invention to provide a method of the type described in the opening paragraph, in which the above drawbacks are avoided. In particular, it is an object of the invention to provide a method with which the flow pattern of fluid streams in a space can be determined dynamically, in situ, in a relatively simple and unambiguous manner and at relatively low cost. To this end, a method according to the invention is characterized by the measures of claim 1.

Determination of a flow pattern of fluid flows in a space offers the advantage that it can be accurately determined how, for instance, temperature and flow velocity distributions in the space occur. With a method according to the present invention the flow pattern of a fluid stream can be determined in a relatively simple manner and with economic means, for instance from an inlet in a space, in particular by determining a so-called central line thereof and making use of the fact that, in principle, the distribution of magnitudes in an air stream is distributed normally, at least in the known manner, around this central line, at least can be properly estimated. The central line is determined by the connecting line between a relevant inlet and the positions of the maximum or minimum value measured, at least calculated, of the magnitude in the gas stream at the level of the or each sensor. Whether this is determined by the minimum or maximum value, of course depends on the value of the magnitude of the inflowing fluid with respect to the relevant magnitude in the further space. When, for instance, inflowing fluid is relatively cold, use will be

NEW CLAIMS

1. A method for determining a flow pattern of a fluid in a space, wherein:

- a fluid is passed via at least one inlet into the space, wherein

- in a first position, at a distance from the at least one inlet, a first sensor (15) is provided with which in at least three fixed points spaced apart along a line a parameter of said fluid is measured in at least part of the fluid stream for determining a parameter distribution;

- determining, on the basis of the measured distribution, at least in respect of the measured parameter, the location of the maximum or minimum value of the relevant parameter on said line; and

- determining, on the basis of at least the position of this maximum or minimum value, the flow pattern in the space.

2. A method according to claim 1, wherein at least in or near the or each inlet the fluid throughput is measured.

3. A method according to claim 1 of 2, wherein in or near the at least one inlet the inflow direction of the fluid is determined.

4. A method according to any one of the preceding claims, wherein in or near the at least one inlet the relevant parameter of the fluid is measured, wherein preferably, moreover, at a distance from the fluid stream a comparable parameter in the space is determined.

5. A method according to any one of the preceding claims, wherein in the fluid stream in said first position at least three recording elements (T_1, T_2, T_3) for the relevant parameter are arranged at a distance from each other, in particular above each other, for measuring the local value of the relevant parameter, wherein on the basis of the value differences the

position of the maximum or minimum value in said first position is determined.

6. A method according to any one of the preceding claims, wherein said fluid parameter is measured contactlessly, preferably acoustically.

7. A method according to any one of the preceding claims, wherein in at least two positions placed one after the other in the flow direction of the fluid stream the distribution, at any rate at least two values, are measured.

8. A method according to any one of the preceding claims, wherein on the basis of at least the flow pattern of the fluid stream the throughput of the at least one inlet is regulated and/or the direction of inflow of the fluid into, at least from the at least one inlet is regulated and/or at any rate a part of the fluid stream is passed from the space via at least one outlet, wherein in, at any rate near the at least one outlet the relevant parameter of the fluid stream and preferably also the throughput and/or the composition thereof is measured.

9. A method according to any one of the preceding claims, wherein as fluid a gas is passed into a space and wherein as parameter at least one of the following parameters is measured:

temperature, flow velocity, flow direction,
pressure, concentration of a component, density.

10. A method according to claims 9, wherein the gas is passed into a space substantially filled with gas.

11. A method according to claim 9, wherein the gas is passed into a space substantially filled with liquid or suspension.

12. A method according to any one of the preceding claims, wherein as fluid a liquid is passed into a space and wherein as parameter is measured at least one of the following parameters is measured:

temperature, flow velocity, flow direction,
pressure, concentration, density.

13. A method according to claim 12, wherein the liquid is passed into a space substantially filled with liquid.

14. An apparatus for determining a flow pattern of a fluid in a space, comprising:

- at least one first sensor (15), which first sensor (15) is provided with at least three recording elements (T_1, T_2, T_3) for measuring a parameter in at least three points spaced apart along a line; and
- a process unit to which the values of the parameter measured in said points can be passed;
- wherein said process unit is provided with an algorithm for determining, during use, on the basis of at least the measured values the position of the maximum or minimum value of the relevant parameter in the fluid stream at the level of the said relevant first measuring device and, at least partly on the basis thereof, determining the flow pattern.

15. An apparatus according to claim 14, wherein at least each first sensor is arranged for contactlessly measuring said parameter, preferably acoustically.

16. An apparatus according to claim 14 or 15, wherein the or each first sensor comprises at least three recording elements for the relevant parameter placed at a mutually known distance, such that the recording elements are placeable for use substantially along a straight or curved line in the fluid stream, while a preferably regular pattern of recording elements in a space can be obtained with a series of first sensors.

17. An apparatus according to any one of claims 14-16, wherein a series of first sensors is arranged to measure said parameter in at least two and preferably at least three positions on a straight or curved line, such that a preferably regular pattern of recordings can be obtained with said series first sensors.

18. An apparatus according to any one of claims 14-17, wherein at least the or each first sensor the process unit and fluid inlet regulating

means and/or fluid outlet regulating means are incorporated into a regulating cycle, in which during use the fluid inlet regulating means and/or fluid outlet regulating means provide data with respect to the fluid stream, which data are processed by the process unit, such that at least partly on the basis of these data the fluid inlet regulating means and/or fluid outlet regulating means are regulated.

19. An apparatus according to any one of claims 14-18, wherein the recording elements at least comprise temperature recording elements.

20. A space, provided with an apparatus according to any one of claims 14-19, wherein a preferably regular pattern of at least first sensors is provided, in particular recording elements thereof in at least a part of the space between at least one fluid inlet and at least one fluid outlet.

21. A space according to claim 20, wherein the at least one fluid inlet is provided relatively high in the space.

experience. It will be clear that, in general, no ideal adjustment will thus be obtained. Moreover, this can only be examined by measuring afterwards and not in situ.

Furthermore, when mixing via liquids, for instance in the preparation of paints and lacquers, foodstuffs, medicaments and the like, it is highly important that a complete mixing is obtained. Here, too, it has hitherto not been possible to measure in situ the flow pattern of a liquid stream passed into a tank or the like.

It is an object of the invention to provide a method of the type described in the opening paragraph, in which the above drawbacks are avoided. In particular, it is an object of the invention to provide a method with which the flow pattern of fluid streams in a space can be determined dynamically, in situ, in a relatively simple and unambiguous manner and at relatively low cost. To this end, a method according to the invention is characterized by the measures of claim 1.

Determination of a flow pattern of fluid flows in a space offers the advantage that it can be accurately determined how, for instance, temperature and flow velocity distributions in the space occur. With a method according to the present invention the flow pattern of a fluid stream can be determined in a relatively simple manner and with economic means, for instance from an inlet in a space, in particular by determining a so-called central line thereof and making use of the fact that, in principle, the distribution of magnitudes in an air stream is distributed normally, at least in the known manner, around this central line, at least can be properly estimated. The central line is determined by the connecting line between a relevant inlet and the positions of the maximum or minimum value measured, at least calculated, of the magnitude in the gas stream at the level of the or each sensor. Whether this is determined by the minimum or maximum value, of course depends on the value of the magnitude of the inflowing fluid with respect to the relevant magnitude in the further space. When, for instance, inflowing fluid is relatively cold, use will be

Claims

1. A method for determining a flow pattern of a fluid in a space, wherein:

- a fluid is passed via at least one inlet into the space,
- in a first position, at a distance from the at least one inlet, a distribution of a fluid magnitude, at least a similar magnitude is measured at least twice and preferably at least thrice at a mutual distance in at least a part of the fluid stream,
- determining, on the basis of the measured distribution, at least in respect of the measured magnitude, the position of the maximum or minimum value of the relevant magnitude, and
- determining, on the basis of at least the position of this maximum or minimum value, the flow pattern in the space, preferably by means of an algorithm.

2. A method according to claim 1, wherein at least in or near the or each inlet the fluid throughput is measured.

3. A method according to claim 1 of 2, wherein in or near the at least one inlet the inflow direction of the fluid is determined.

4. A method according to any one of the preceding claims, wherein in or near the at least one inlet the relevant magnitude of the fluid is measured, wherein preferably, moreover, at a distance from the fluid stream a comparable magnitude in the space is determined.

5. A method according to any one of the preceding claims, wherein in the fluid stream in said first position at least two, preferably at least three recording elements for the relevant magnitude are arranged at a distance from each other, in particular above each other, for measuring the local value of the relevant magnitude, wherein on the basis of the value differences the position of the maximum or minimum value in said first position is determined.

6. A method according to any one of the preceding claims, wherein said fluid magnitude is measured contactlessly, preferably acoustically.

7. A method according to any one of the preceding claims, wherein in at least two positions placed one after the other in the flow direction of the fluid stream the distribution, at any rate at least two values, are measured.

8. A method according to any one of the preceding claims, wherein on the basis of at least the flow pattern of the fluid stream the throughput of the at least one inlet is regulated and/or the direction of inflow of the fluid into, at least from the at least one inlet is regulated and/or at any rate a part of the fluid stream is passed from the space via at least one outlet, wherein in, at any rate near the at least one outlet the relevant magnitude of the fluid stream and preferably also the throughput and/or the composition thereof is measured.

9. A method according to any one of the preceding claims, wherein as fluid a gas is passed into a space and wherein as magnitude at least one of the following magnitudes is measured:

temperature, flow velocity, flow direction,
pressure, concentration of a component, density.

10. A method according to claims 9, wherein the gas is passed into a space substantially filled with gas.

11. A method according to claim 9, wherein the gas is passed into a space substantially filled with liquid or suspension.

12. A method according to any one of the preceding claims, wherein as fluid a liquid is passed into a space and wherein as magnitude is measured at least one of the following magnitudes is measured:

temperature, flow velocity, flow direction,
pressure, concentration, density.

13. A method according to claim 12, wherein the liquid is passed into a space substantially filled with liquid.

14. An apparatus for determining a flow pattern of a fluid in a space, comprising:

- at least one first measuring device, which first device can measure a magnitude in at least two and preferably at least three different positions, and
- a process unit to which the values of the measured magnitude can be passed,
- wherein the process unit is provided with an algorithm for determining, during the use on the basis of at least the measured values, the position of the maximum or minimum value of the relevant magnitude in the fluid stream at the level of the relevant first measuring device and, at least partly on the basis thereof, determining the flow pattern.

15. An apparatus according to claim 14, further comprising at least one second measuring device for the relevant magnitude, for positioning in or near a fluid inlet.

16. An apparatus according to claim 14 or 15, further comprising at least one throughput sensor for positioning in or near a fluid inlet or fluid outlet.

17. An apparatus according to any one of claims 13-16, wherein at least each first measuring device comprises at least one first sensor for the relevant magnitude, arranged for placement in a fluid stream.

18. An apparatus according to any one of claims 13-17, wherein at least each first measuring device is arranged for contactlessly measuring said magnitude, preferably acoustically.

19. An apparatus according to claim 17, wherein the or each first sensor comprises at least two and preferably three recording elements for the relevant magnitude placed at a mutually known distance, such that the recording elements are placeable for use substantially along a straight or curved line in the fluid stream, while a preferably regular pattern of recording elements in a space can be obtained with a series of first sensors.

20. An apparatus according to any one of claims 13-19, wherein the or each first measuring device is arranged to measure said magnitude in at least

two and preferably at least three positions on a straight or curved line, such that a preferably regular pattern of recordings can be obtained with a series of first measuring devices.

21. An apparatus according to any one of claims 13-20, wherein at least the or each first measuring device, the process unit and fluid inlet regulating means and/or fluid outlet regulating means are incorporated into a regulating cycle, in which during use the fluid inlet regulating means and/or fluid outlet regulating means provide data with respect to the fluid stream, which data are processed by the process unit, such that at least partly on the basis of these data the fluid inlet regulating means and/or fluid outlet regulating means are regulated.

22. An apparatus according to any one of claims 13-21, wherein the recording elements at least comprise temperature recording elements.

23. A space, provided with an apparatus according to any one of claims 13-22, wherein a preferably regular pattern of at least first sensors is provided, in particular recording elements thereof in at least a part of the space between at least one fluid inlet and at least one fluid outlet.

24. A space according to claim 23, wherein the at least one fluid inlet is provided relatively high in the space.

25. A process unit for use in a method according to any one of claims 1-13, in an apparatus according to any one of claims 14-22 or in a space according to any one of claims 23 or 24.

26. A sensor, in particular a temperature sensor for use in a method according to any one of claims 1-13, in an apparatus according to any one of claims 14-20, in a space according to any one of claims 23 or 24 or in a process unit according to claims 25.

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

Prins, A.W.
VEREENIGDE
Nieuwe Parklaan 97
NL-2587 BN The Hague
PAYS-BAS

Kopie n/naar | TERMIJN | 16 OKT 2001
Beantwoord | Bericht gezonden aan
Voorl. def.
MAP

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing *(day/month/year)* 05.10.2001

Applicant's or agent's file reference
P11141PC00

IMPORTANT NOTIFICATION

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IB00/00865	28/06/2000	28/06/1999

Applicant
KATHOLIEKE UNIVERSITEIT LEUVEN et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

   The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

   Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

   For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/
European Patent Office
D-80298 Munich
Tel. +49 89 2399 - 0 Tx: 523656 epmu d
Fax: +49 89 2399 - 4465

Authorized officer
Conner, M
Tel.+49 89 2399-2241

Form PCT/IPEA/416 (July 1992)